Chapter 3
Why Adopt a Seismic Code?

FIGURE 3.1 Most of the building damage in the 1989 Loma Prieta earthquake was to older unreinforced masonry buildings built before the adoption of seismic codes. (Photo: Rob Olshansky)

The term *seismic code* refers to the seismic design requirements included within building codes. In the past, local governments sometimes viewed the seismic sections of the model codes as optional, adopted at local discretion. Now seismic provisions are fully integrated into all three model codes. Local governments should adopt the latest version of a model code in its entirety, including the seismic sections, in order to be operating at the current standard. This point is very important and is emphasized throughout this book.

Seismic Codes Are Effective

Experience with recent earthquakes in the United States and throughout the world shows that seismic codes work. Cities with seismic codes suffer much less damage than those without such codes.

The Loma Prieta earthquake clearly illustrates the effectiveness of seismic codes. Occurring on October 17, 1989, this earthquake measured 7.1 on the Richter scale and was the strongest to affect a U.S. city since the 1964 Alaskan earthquake.[1] It shook the San Francisco Bay Area and killed sixty-three people. Two-thirds of the deaths were a result of the Cypress viaduct collapse. Although the ground-shaking was intense within the metropolitan area, few buildings collapsed. Most of the damage occurred to unreinforced masonry buildings built before the adoption of seismic codes. Nearly all major reinforced concrete structures built after World War II survived without collapse. Even at the quake's epicenter new buildings and buildings located on firm ground suffered little damage. Informed observers attribute the success to the required UBC seismic codes.[2] This example illustrates that code requirements reduced the damage and loss of life during this moderate earthquake.

The 1994 Northridge, California, earthquake shows similar evidence. Almost all the buildings in the affected area were built during the past fifty years under one of the UBC seismic codes. Virtually all buildings, even in the areas of strongest shaking, remained standing and allowed for safe evacuation of occupants. Regrettably, one apartment building collapsed on its residents, and two high-occupancy concrete-frame buildings collapsed, fortunately with no occupants at the time.[3] Still, these three buildings were built under an older version of the UBC code, and damage and life loss would have been immeasurably greater without the seismic-resistant construction prevalent in the San Fernando Valley.

A Kyoto University study of the 1995 earthquake in Kobe, Japan, Richter magnitude 6.9, found that damage to reinforced concrete buildings closely paralleled improvements to seismic provisions in the Japanese building code. More than 55 percent of pre-1970 buildings (old version of code) were severely damaged, compared with no post-1980 buildings (newest version of code). Similarly, steel buildings built before 1970 sustained severe damage, compared with little damage in post-1981 buildings.[4] Ohbayashi Corporation studied buildings it had constructed in Kobe and found that 58 percent of pre-1971 buildings were damaged, compared with 28 percent of 1972-80 buildings and only 16 percent of post-1981 buildings.[5]

In contrast, a Richter magnitude 6.9 earthquake in Armenia in 1988 destroyed entire communities and killed 25,000 people. This disaster has been attributed to several factors: design deficiencies; poor quality of construction; and the earthquake's intensity exceeding that anticipated by the code.[6] Similar problems exist in much of the United States.

Even smaller earthquakes can cause extensive damage where buildings are not designed for seismic shaking. A Magnitude 5.6 earthquake in 1993 at Scotts Mills, Oregon, caused significant structural damage to a number of unreinforced masonry (brick) buildings in the area.[7] A high school building was significantly damaged and vacated, 16 residences and 54 businesses sustained major damage, and the Oregon State Capitol, in Salem, suffered cracking in the rotunda. The estimated damage cost to public facilities alone was nearly $13 million. This earthquake confirmed the susceptibility of unreinforced buildings to severe damage, even in a minor earthquake.

New lessons are learned from every earthquake and incorporated into U.S. seismic codes. For example, the 1985 Mexico City earthquake confirmed that the local soil conditions are as important to building stability as the epicenter location.[8] In response to this new information, ICBO in the 1988 and 1991 UBC editions has emphasized soil conditions by increasing the force requirements according to the type of underlying soil. *The National Earthquake Hazard Reduction Program (NEHRP) Recommended Provisions* (described on page 8) have also taken into account soil conditions in the latest edition.

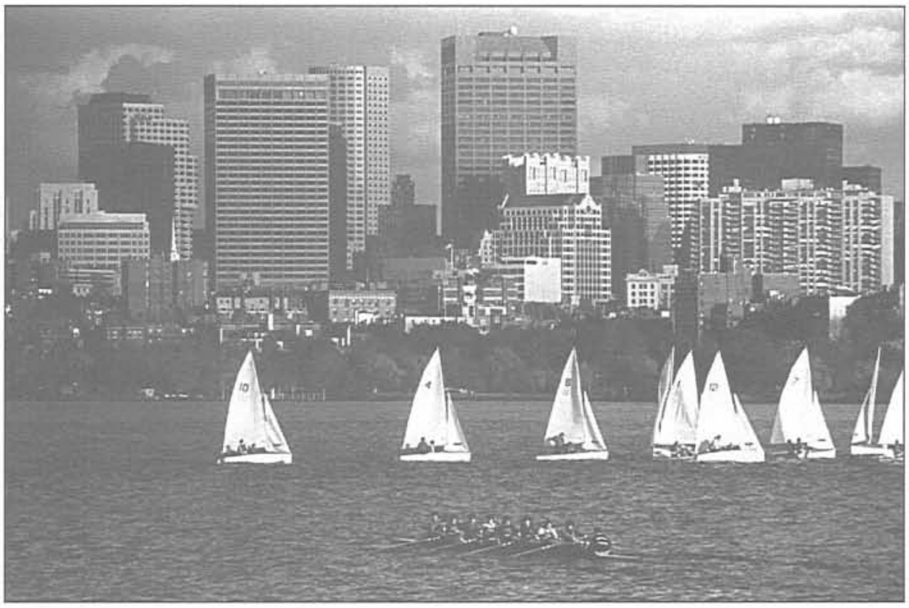

FIGURE 3.2 Lessons about underlying soil conditions learned in the 1985 Mexico City quake can help areas built on fill, such as the Back Bay area of Boston shown above, minimize damage. (Photo: Greater Boston Convention & Visitors Bureau)

Today's Seismic Codes Are Based on More Than Sixty Years of Earthquake Experience

Seismic codes in use now reflect a long history of learning from earthquakes and represent the collective knowledge of hundreds of design and construction professionals. The following is a brief account of that history. See Appendix A for a more detailed account.

The earliest seismic design provisions in the U.S. were introduced in the appendix to the 1927 *Uniform Building Code*, the first edition of the UBC. By the 1950s, some California municipalities had adopted additional seismic-resistant design and material specifications. The 1949 edition of the UBC contained the first national seismic hazard map. After the 1971 San

Earthquake Magnitude and Intensity

Earthquake *magnitude* is a measure of the absolute size of an earthquake so that we may compare earthquakes with one another. Generally speaking, earthquakes that release more energy

- shake for a longer amount of time,
- affect a wider area, and
- produce more violent shaking near the source.

Because we cannot measure the energy released by an earthquake, Charles Richter in 1935 devised a substitute measure—the Richter magnitude scale. The scale is based on what a seismograph would measure; it has no inherent meaning of its own. The Richter scale is logarithmic, and each whole number increase in the scale represents approximately a 31.5-fold increase in energy release: that is, a magnitude 7 earthquake releases about 31.5 times more energy than does a magnitude 6 earthquake. Several different magnitude scales are now in common use, and they all share basic characteristics with the Richter Scale.

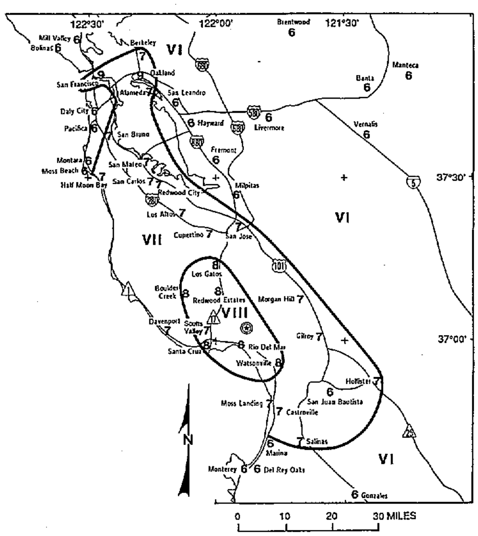

FIGURE 3.3 The Loma Prieta, California, earthquake of 1989 had a magnitude of 7.1, but intensities in the affected area ranged from MMI VII to IX. (Source: USGS Circular 1045, 1989)

Shortly after an earthquake occurs, the *surface wave magnitude or body wave magnitude* is often reported. The scale that most accurately represents the energy of an earthquake is the *moment magnitude scale*. For smaller earthquakes (less than magnitude 6), the scales are nearly identical, but only the moment magnitude scale can distinguish differences among very large earthquakes.

Earthquake *intensity* is a measure of the actual shaking experienced at a location. The United States uses the Modified Mercalli Intensity Scale, a twelve-point qualitative scale that describes observable effects of earthquakes. For example, Intensity VIII is described, in part, as "damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures . . . fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned." Whereas magnitude is an inherent quality of an earthquake, intensity generally decreases with greater distance from the earthquake's center. Intensity is a very useful measure because it describes what is most important to society—the degree of damage to structures built by humans.

Fernando earthquake, revisions were made to the 1973 UBC, and new requirements were introduced in the 1976 edition.[9]

Early in the 1970s the National Science Foundation (NSF) funded a project, under the guidance of the National Bureau of Standards (NBS, now the National Institute of Standards and Technology), to evaluate existing earthquake-resistant design provisions. This extensive multi-year project relied on the input of a large number of seismic design experts and resulted in a 1978 report by the Applied Technology Council titled *Tentative Provisions for the Development of Seismic Regulations for Buildings (ATC 3-06).*

Under a contract with the Federal Emergency Management Agency (FEMA), the Building Seismic Safety Council (BSSC, formed in 1979 within the National Institute for Building Sciences, NIBS) revised ATC 3-06 by a consensus of its members. In 1985 FEMA released the *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings*, commonly called the *NEHRP Provisions*. Although not a code, the *NEHRP Provisions* are designed to provide guidance to the writers of building codes. FEMA and BSSC continue to update the *NEHRP Provisions* every three years, with the latest edition being published in 1994. The 1997 edition is due out in December 1997.

All Three Model Codes Contain State-of-the-Art Seismic Requirements

The past two decades have seen great strides in the knowledge of building responses to earthquakes. Based on the collective efforts of engineers, scientists, and tradespeople, the *NEHRP Provisions* contain seismic design provisions that are technically advanced and widely accepted.

Since 1992 all three model codes require seismic design standards consistent with the *NEHRP*

Modified Mercalli Intensity Scale

Figure 3.4 Percentage of Buildings Expected in Each Damage State for Various Shaking Intensities: Buildings Designed for Seismic Zone 4 under the 1991 UBC

Size of Earthquake (Magnitude)		Expected MMI	Standardized Damage States				
			A	B	C	D	E
6.0-6.5	7.5-8.0		None	Slight	Moderate	Extensive	Complete
Distance to Fault							
30 mi.	50 mi.	VII	60-90%	10-40%	1-5%	<1%	0
5 mi.	40 mi.	VIII	35-60%	35-45%	10-30%	<5%	<1%
1 mi.	30 mi.	IX	25-40%	25-40%	20-40%	3-10%	<2%
—	3 mi.	X	5-25%	5-25%	40-70%	10-30%	<5%

Source: EERI Ad Hoc Committee (see note 12).

MMI VI: Ground-shaking felt by all; some cracked plaster; broken dishes and glassware. (Photo: Caltech EERL)

MMI VII: Disturbance frightens all; cracked chimneys; cracking in unreinforced masonry structures. (Photo: Rob Olshansky)

MMI VIII: Causes near panic; partial collapse of unreinforced masonry structures. (Photo: Rob Olshansky)

MMI IX: General panic; ground-cracking; considerable damage in buildings designed to seismic code. (Photo: J. David Rogers)